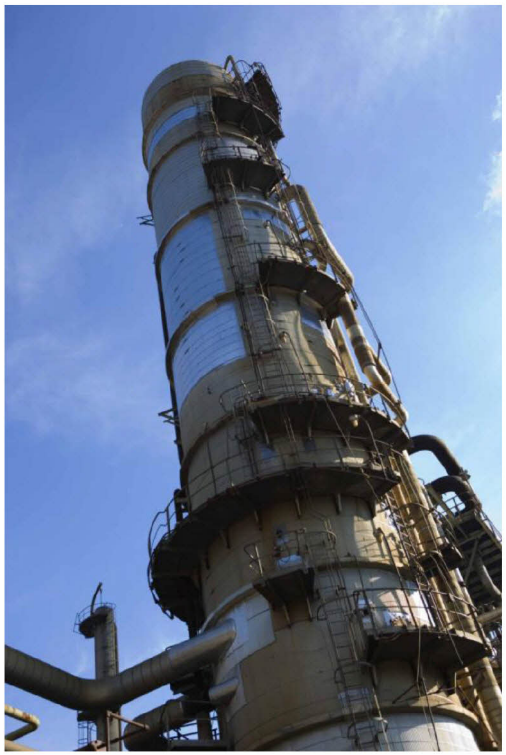
Embrittlement Mechanisms



Senior Analyst and Inspector Training
Crude Units

Sigma Embrittlement

Characteristics

- Occurs rapidly in the ferrite phase of 300 Series SS castings and weld metal when exposed to 1100-1700°F (600-925°C)
- Can occur in wrought products over very long period of time
- Sigma reduces toughness at temperatures below 1000°F (538°C)
- Sigma phase makes weld repairs more difficult
- 316 and 347 SS embrittle more rapidly than 304 SS

Preventing Failures From Sigma Phase Embrittlement

- Limit ferrite content of weld metal to 10% max. (3% min. to avoid hot cracking)
- Avoid shock loadings when embrittled material is cool (<1000°F/538°C)
- Tube hangers are often sigma embrittled due to their high operating temperatures — handle hangers carefully at shutdown; be prepared to replace some

885°F (475°C) Embrittlement

Environment:	Operation at temperatures in 700-950°F (370-510°C) range
Mechanism:	Embrittlement of ferritic or martensitic stainless steels with ≥ 12% Cr (400 Series)
Effects:	Ductile to brittle transition temperature increases
Restoration:	PWHT restores the material ductility

Note: This embrittlement mechanism prevents use of 400 Series stainless steels for pressure-containing components in the hotter locations of crude units – embrittlement is not a significant concern for 400 Series stainless linings but 12 Cr trays may embrittle

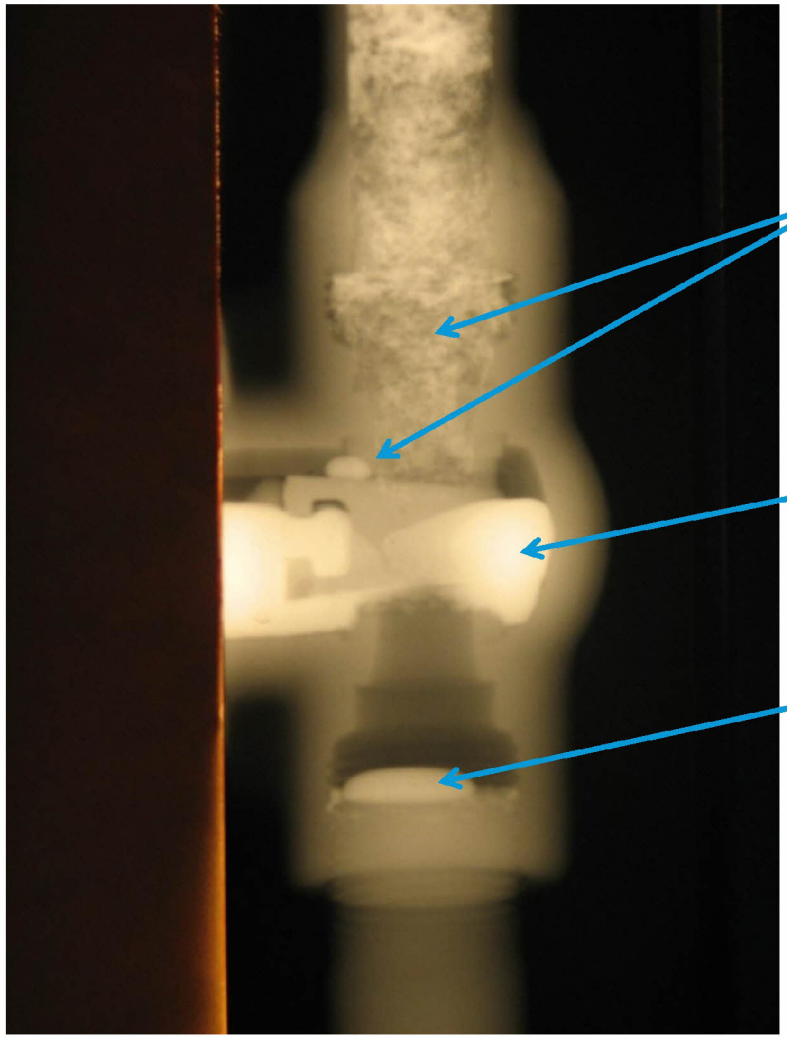
Liquid Metal Embrittlement

- Liquid metal embrittlement (LME) is characterized by rapid penetration of a solid metal by a liquid (molten) metal, often at the grain boundaries, leading to brittle fracture
- Molten zinc (galvanized steel) and mercury (which can be found in certain crudes) are the primary concerns for the refining industry
- Some organizations have limited the operating temperature of galvanized steel because of the possibility of LME
- ***Under no circumstances should galvanized steel be welded to stainless steel!***
- Stress promotes LME, but sometimes contact of molten metal is enough to lead to damage

Liquid Metal Embrittlement – Mercury

- In crude oil processing units, failures due to the presence of mercury appear to occur most commonly in the overhead systems where mercury collects
- A number of failures of admiralty tube bundles have been reported due to the presence of mercury in overhead systems
- 400 Alloy is especially sensitive to mercury
- The only way to prevent mercury problems is to remove it before it gets into equipment
- Refinery fires can lead to LME
- See API 571 Damage Mechanism #52

Mercury Accumulation in Low Point Bleeder



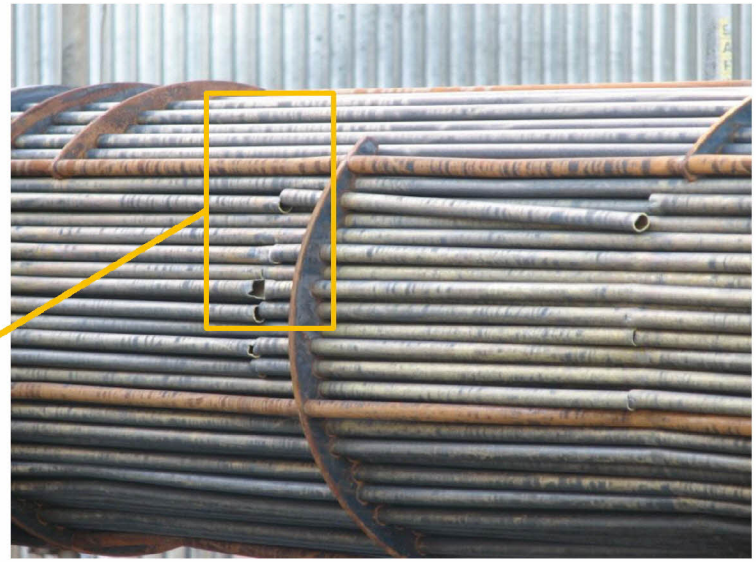
This area should not have the white scattered stuff, should be black (white stuff is Mercury)

Mercury around the seat of the valve

Mercury puddle on top of the bull plug

The valve was a low point bleeder downstream of the crude unit stabilizer column

Mercury Embrittlement of Admiralty Brass Heat Exchanger Tubes



- After the bundle was rolled over, the tubes started breaking
- The bottom of the bundle where the tubes rested on the supports are cracked